NATIONAL BUREAU OF STANDARDS REPORT

3012

QUARTERLY REPORT
ON
EVALUATION OF REFRACTORY QUALITIES OF CONCRETES
FOR JET AIRCRAFT WARM UP, POWER CHECK,
AND MAINTENANCE APRONS

by

W. L. Pendergast, R. A. Clevenger, Edward C. Tuma

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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- Office of Basic Instrumentation
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NBS PROJECT 0903-21-4428 | December 31, 1953 | **NBS REPORT** 3012

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W. L. Pendergast, R. A. Clevenger, Edward C. Tuma
Refractories Section
Mineral Products Division

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Approved:

R. A. Heindl, Chief
Refractories Section

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

QUARTERLY REPORT
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TECHNICAL REQUIREMENTS

The technical requirements are the same as those given in the NBS Report 2832 with a change in one of the five conditions of exposure of the concrete specimens before testing. The exposure before testing the specimens are as follows [1]:

1. Twenty-eight days in fog-room.
2. Seven days in fog-room, plus 21 days in ordinary laboratory air.
3. Cured as in No. 2 plus heating at 250°C.
4. Cured as in No. 2 plus heating at 500°C.
5. Cured as in No. 2 plus heating at 1000°C.

1. INTRODUCTION

The objective of the investigation is the determination of the physical properties of concretes that will evaluate their suitability for use in jet aircraft warm-up, power check, and maintenance aprons.

2. MATERIALS: PREPARATION AND TESTING

2.1 Cements

The specific gravity of the three hydraulic cements included in this project has been determined* by the A.S.T.M. method, Designation C188 [2]. It was also determined by a modification of that method which included substituting distilled water for kerosene and adding 5 drops of emulsified silicone defoamer.

2.2 Aggregates

Seven tons of building brick, West Virginia, hard fare, one of the ceramic aggregates included in this project, have been crushed and screened. Eleven screens are necessary to grade the aggregate. Sufficient amount of the eleven screen sizes from - 1 1/2" to -100 have been screened. The properties of the aggregate determined were: the percentage of wear in the Los Angeles abrasion test; the correction factor for use with the air meter; the bulk specific gravity, the percent absorption; and the unit weight in pounds per cubic foot.

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* By the Concreting Materials Section, Mineral Products Division, National Bureau of Standards.

2.3 Concretes

In the preceding report [3] information was given relative to the properties of three fresh concretes designed with Bluestone as an aggregate. Since that time five complete sets of specimens of these concretes containing either portland, portland pozzolan, or high alumina hydraulic cement, have been cured. The fog-room curing for one set of each concrete was 28 days. The other four sets of each concrete were cured for seven days in the fog-room plus 21 days under ordinary laboratory conditions. Three of the latter four sets were subjected to heat exposures of either 500, 750, or 1000°C. All specimens have been tested.

During the current quarter 34 one-cubic foot trial batches of concretes were designed, mixed, and specimens fabricated.

Sixteen of these 34 concretes were designed with olivine aggregate. Six of these 16 contained portland cement, six portland pozzolan, and four high alumina hydraulic.

Also, twelve of the group of 34 concretes were designed with crushed building brick aggregate. Four of these 12 contained portland, portland pozzolan or high alumina hydraulic cement.

Furthermore, another six of the 34 concretes were designed with olivine aggregate but substituting the natural aggregate, White Marsh sand, for 50 percent of the fines (+50, +100, and -100). Two each of these six concretes contained portland, portland pozzolan, or high alumina hydraulic cement.

Grouping the concretes according to the aggregates used in their design, systematic changes were made in each such group in the ratio of coarse to fine aggregate, the amount of mixing water and air-entraining agent. These changes in design of the concretes were made to yield air contents of 4 1/2 percent, plus or minus 1 1/2 percent, a slump of 2-inches, and a flexural strength of 650 psi after 28-day fog-room curing.

3. RESULTS AND DISCUSSION

3.1 Cements

The specific gravity of the three cements, as determined by two methods follows:

Identity	Specific Gravity Method* (A)	Specific Gravity Method* (B)
North American Portland	3.11	3.26
Green Bag Portland Pozzolan	3.13	3.14
Universal Atlas Lumnite	3.09	3.13

* The results given in column (A) were determined by the ASTM Method [2] and those in column (B) by the modified method previously described.

The purpose of determining the specific gravity of these cements in water was to obtain a value for this property that would be comparable with the value as it occurs in concrete at the time the test for air content is made.

3.2 Aggregates

All dense aggregates, used in this phase of the project, were graded to conform with Budock's specification No. 45Ya [4]. The coarse sizes are to conform with paragraph 2-05 of this specification and the fines to paragraph 2-03.

Figure 1 shows the permissible limits of the combined coarse and fine aggregates as required by specification 45Ya. It also defines the range used in designing the concretes for this project.

3.3 Concretes

Table 1 gives the results of the tests for the three concretes designed with Bluestone aggregate after eight different exposures. The portland-Bluestone concrete was designed using a six and one-half sack mix, the pozzolan-Bluestone concrete a seven sack mix, and the Lumnite-Bluestone concrete a seven and one-half sack mix. All other properties of the fresh concretes are given in a previous report [3].

The results indicate that the concretes met the specified strength requirement of 650 psi after a 28-day fog-room curing. However, the rapid decrease in strength after heat exposure of 500°C and above indicate that concretes designed with Bluestone, a dolomitic-limestone, aggregate are possibly not suitable for such exposures.

Table 2 gives the results of tests on each of 34 one-cubic foot trial mixes of concretes. Results are also given for the one concrete (olivine aggregate with high-alumina hydraulic cement) that was selected as complying with the specified requirements. Three five-cubic foot batches of this selected concrete was mixed and specimens, for a complete series of tests, were fabricated.

The results indicate that due to the weakness of olivine as an aggregate there may be some difficulty in selecting a design using either portland or portland pozzolan, that will meet the flexural strength requirements. This maybe accounted for becasuse of the higher 28-day compressive strength of the high-alumina hydraulic mortar which is approximately 1500 psi greater than that of either portland or portland pozzolan mortar.

The results indicate that there will be no difficulty in selecting a design for concretes, with crushed building brick as the aggregate and any one of the three cements, having the required strength.

The results of the six trial mixes, using a combination of olivine and White Marsh sand as aggregate, indicate that changes in design will be necessary. The purpose of the incorporation of a natural aggregate, as fines, was because of its greater availability and ease of preparation and consequently both lower cost and speedier production of concrete.

The air contents of the concretes, as determined by the pressure method and also by the gravimetric method are given in table 2. Swanberg and Thomas [5] found there was a direct relation between the values obtained for entrained air in concrete as determined by the two methods. In their work a specific gravity of 3.15 was used in calculating air by the gravimetric method. The air contents, as determined by the two methods, of a number of concretes included in this project are shown graphically in figure 2. These concretes all contained olivine as the aggregate but varied in the type and amount of cement used. The graph shows a direct relation between the results as determined by the two methods. The pressure method consistently gives higher air content values in concretes with olivine as the aggregate. However, additional data indicates that in concretes with Bluestone as the aggregate the values ~~fir~~ for air content determined by the pressure method fall slightly below the line describing a direct relation.

In calculating the percent air content, of the concretes by the gravimetric method, each of three values was used for the specific gravity of the cements. The values were, that determined in water (this method has been described previously) the ASTM method [2], and 3.15, which is permitted when the specific gravity has not been actually determined. The direct relation, for the air contents of concrete determined by the pressure method and the gravimetric method respectively, more nearly approaches the ideal when making use of the specific gravity values of the cements determined in water. This is especially true of the concretes containing portland cement.

3.4 Conference

Messrs L. A. Palmer, M. P. Harrington, and P. Knoop, Bureau of Yards and Docks, conferred at this Bureau on November 16, 1953 with R. A. Heindl and W. L. Pendergast of the Refractories Section relative to this project. The conference was a result of the transfer of the administration of the project to the Bureau of Yards and Docks at Washington from Port Hueneme. The program of the project, the method of attack, and the inclusion of additional work was discussed.

Mr. M. P. Harrington visited this Bureau during the latter part of December to obtain information on the size, shape, and number of specimens necessary for a complete test. The present plans are that the NAVCERELAB are to fabricate test specimens and forward them to the Bureau for test. It has also been suggested that we include in our test data the, "Depth of Wear", as well as the "Weight of Dust" when reporting abrasion loss.

REFERENCES

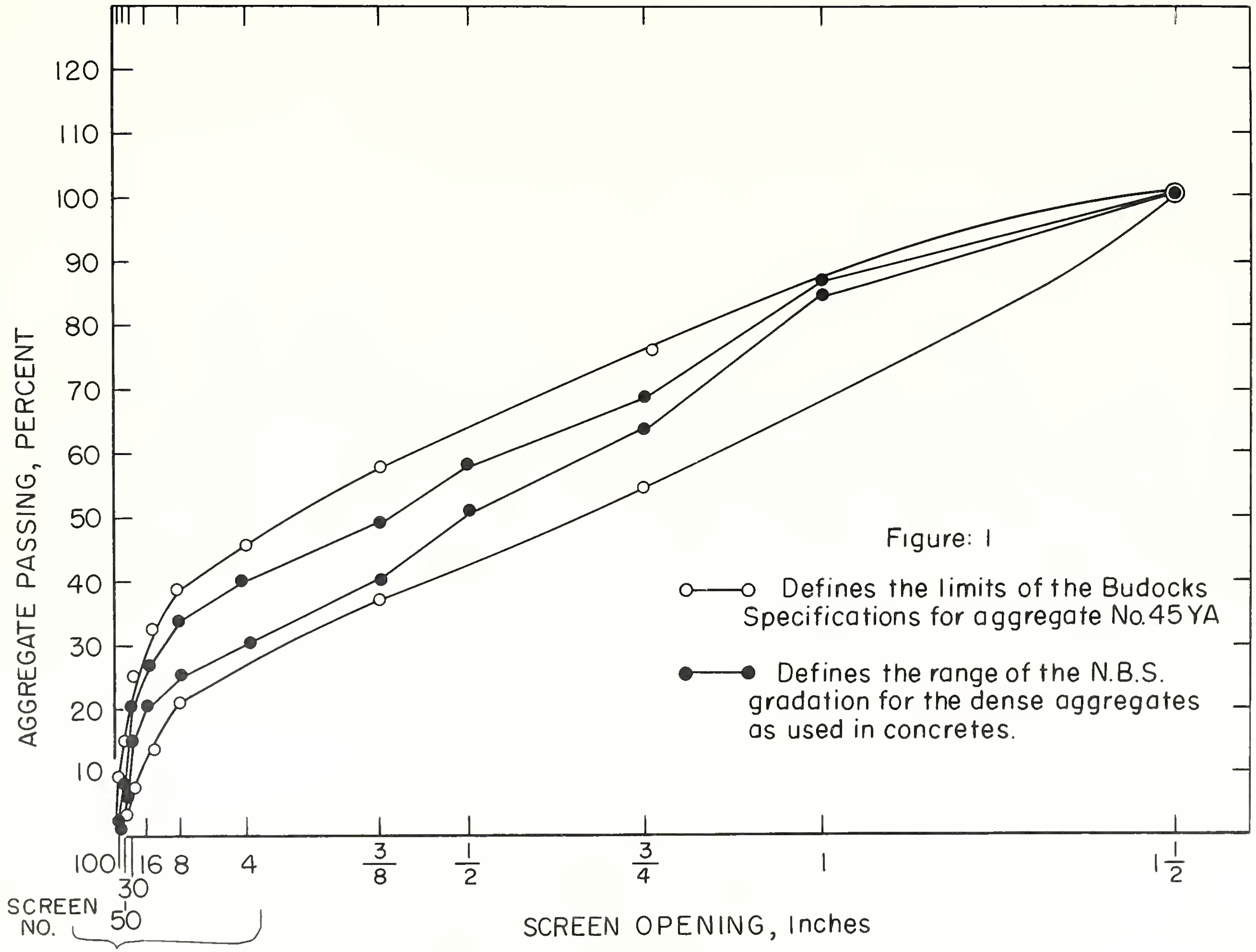
[1] The substitution of a 250°C exposure for the 750°C exposure was discussed during the November 16 conference and authorized in a letter to this Bureau dated November 20, 1953.

[2] Standard Method of Test for Specific Gravity of Hydraulic Cement. 1952 Book of A.S.T.M. Standards, Part 3.

[3] N.B.S. Report No. 2832.

[4] Specification for Portland Cement Concrete Pavement for Airports. Department of the Navy, Bureau of Yards and Docks.

[5] The Measurement of Air Entrained in Concrete. John H. Swanberg and T. W. Thomas Proceedings. A.S.T.M., Vol. 47, p. 869, 1947.



120
110
100
90
80
70
60
50
40
30
20
10
AGGREGATE PASSING, PERCENT
100
50
30
16
8
4
3/8
1/2
3/4
1
1 1/2
SCREEN NO.
SCREEN OPENING, Inches
Figure: 1
Defines the limits of the Budocks Specifications for aggregate No. 45 YA
Defines the range of the N.B.S. gradation for the dense aggregates as used in concretes.

TABLE 1 - PROPERTIES OF CURED AND HEAT-TREATED CONCRETES

Laboratory Identification[a/]	Proportions by Weight: Cement to Coarse and to Fine Aggregate	Treatments Preceding Test[b/]	Compressive Strength	Flexural Strength	Abrasion Loss	Young's Modulus of Elasticity Dynamic; Longitudinal	Total[c/] Linear Change	Total[d/] Weight Change
			psi	psi	gms	lbs/inch^2 x 10^6	%	%
P-BS	1:3.33:1.57	1	3605			3.427		
		2				5.328	(No ap-	+ 0.65
		3		500	28.2	5.553	preci-	- 0.99
		4		680	11.5	5.872	able	+ 0.91
		5				5.037	change)	- 4.81
		6		140	27.0	1.039	+0.07	- 6.14
		7		75	300.0	.461	+0.04	-11.04
		8		10	e/	f/	+1.35	-37.45
Z-BS	1:3.16:1.45	1	5925			3.145		
		2				5.620	-0.07	+ 0.77
		3		570	13.7	5.809	+0.06	- 0.28
		4		965	9.1	6.119	-0.07	+ 0.98
		5				4.822	+0.02	- 4.71
		6		185	26.0	1.184	+0.05	- 6.40
		7		135	24.2	.780	-0.11	-11.40
		8		8	e/	f/	+2.06	-33.01
L-BS	1:3.01:1.34	1	5030			5.436		
		2				5.914	-0.05	+ 0.28
		3		530	16.5	3.660	-0.02	- 1.07
		4		810	20.0	6.160	+0.02	+ 0.65
		5				3.290	-0.01	- 4.14
		6		155	43.1	.879	+0.08	- 6.83
		7		110	66.7	.214	+0.56	-11.90
		8		15	e/	f/	+1.42	-37.25

a/ The first letters: P=portland cement; Z=portland pozzolan cement; L=high alumina hydraulic cement.
The last letters: BS=Bluestone. Sand and gravel aggregate.

TABLE 2 - PROPERTIES OF FRESH[a] CONCRETES

Identification[b]	Proportions by Weight:Cement to Coarse and to Fine Aggregate	Cement Content	Vinsol Resin by weight of Cement	Water Content	Air Content Gravimetric Method	Air Content Air Meter Method	Slump	Weight of fresh Concrete	Water Cement Ratio	Remarks Fresh Concrete	Flexural Strength	Remarks Cured Concrete
		Sacks/yd³ of Concrete	%	Gals/yd³ of Concrete	%	%	inches	lbs/ft³			psi	
P-O-A	1:4.06:1.91	6.59	.015	36.0	0.61	[illegible].57	2.5	171.86	.49	Harsh; easily placed	560	All aggregate fractured
P-O-B	1:4.06:1.91	6.34	.030	36.0	3.70	4.42	2.5	165.80	.50	Very good	490	Few pull-outs; mostly fractured aggregate
P-O-C	1:3.48:1.64	7.13	.030	39.5	2.90	4.62	4.5	164.94	.49	Easily placed	480	do
P-O-D	1:3.27:1.51	7.74	.030	36.2	2.72	3.72	2.3	167.53	.41	Good; easily placed	615	All aggregate fractured; few small air voids
P-O-E	1:3.44:1.47	7.62	.030	36.1	2.30	3.57	3.0	168.40	.42	Placed well	575	Few pull-outs; few large air voids
P-O-F	1:3.50:1.50	7.59	.030	34.6	2.16	3.02	1.5	169.70	.40	Placed well	---	---
Z-O-A	1:4.06:1.91	6.51	.015	36.0	1.25	1.72	2.3	170.13	.50	Harsh; easily placed	560	All aggregate fractured
Z-O-B	1:4.06:1.91	6.43	.025	36.8	2.16	3.07	2.0	168.40	.51	Fair; slightly on dry side	620	do
Z-O-C	1:3.48:1.64	7.31	.025	39.2	1.36	2.87	3.0	168.40	.48	Placed well but sticky	645	do
Z-O-D	1:3.17:1.46	7.51	.030	38.6	5.91	5.87	4.0	159.74	.46	Placed well; sticky	565	All aggregate fractured; few large air voids
Z-O-E	1:3.37:1.44	7.81	.025	34.0	2.70	2.04	1.5	169.26	.39	Placed fair; sticky	650	Few pull-outs of large aggregate; few large air voids
Z-O-F	1:3.37:1.51	7.78	.025	34.2	1.97	1.92	0.8	170.56	.39	Placed fair	---	---
L-O-A	1:2.75:1.84	7.82	.025	41.7	1.60	2.20	8.0	165.80	.47	Placed well	645	All aggregate fractured
L-O-B	1:2.75:1.84	7.61	.035	39.6	4.75	4.60	5.5	161.03	.46	Placed well but started to set in 30 minutes	620	Few pull-outs mostly aggregate fracture
L-O-C	1:2.53:1.75	8.09	.033	41.5	3.43	4.49	7.0	162.34	.46	Placed well	655	All aggregate fractured
L-O-D	1:3.16:2.11	7.16	.035	35.7	2.60	3.07	1.5	167.97	.44	Placed well	720	All aggregate fractured; few large air voids
L-O-1	1:3.16:2.11	7.09	.035	38.5	2.98	2.92	2.3	166.66	.45	Placed well	---	---
L-O-2	1:3.16:2.11	7.09	.035	38.5	2.98	3.17	2.0	166.66	.45	do	---	---
L-O-3	1:3.16:2.11	7.16	.035	38.5	2.98	3.02	2.0	168.40	.45	do	---	---
P-OWM-B	1:3.46:1.84	6.02	.030	34.20	8.49	c/	4.0	153.68	.50	Placed well	365	All aggregate fractured; large air voids
P-OWM-C	1:3.83:1.78	6.76	.010	33.00	2.20	2.72	1.8	166.66	.43	Fair	545	do
Z-OWM-B	1:3.86:1.82	6.12	.025	33.10	9.40	c/	3.8	153.24	.48	Good	445	do
Z-OWM-C	1:3.78:1.78	6.70	.010	33.50	3.44	3.22	1.8	164.07	.44	Good	560	do
L-OWM-D	1:3.09:2.07	6.52	.040	33.90	9.35	c/	2.8	151.08	.43	Good	570	do
L-OWM-C	1:3.00:2.00	6.94	.025	38.40	4.44	4.69	6.0	157.88	.49	Good	495	do

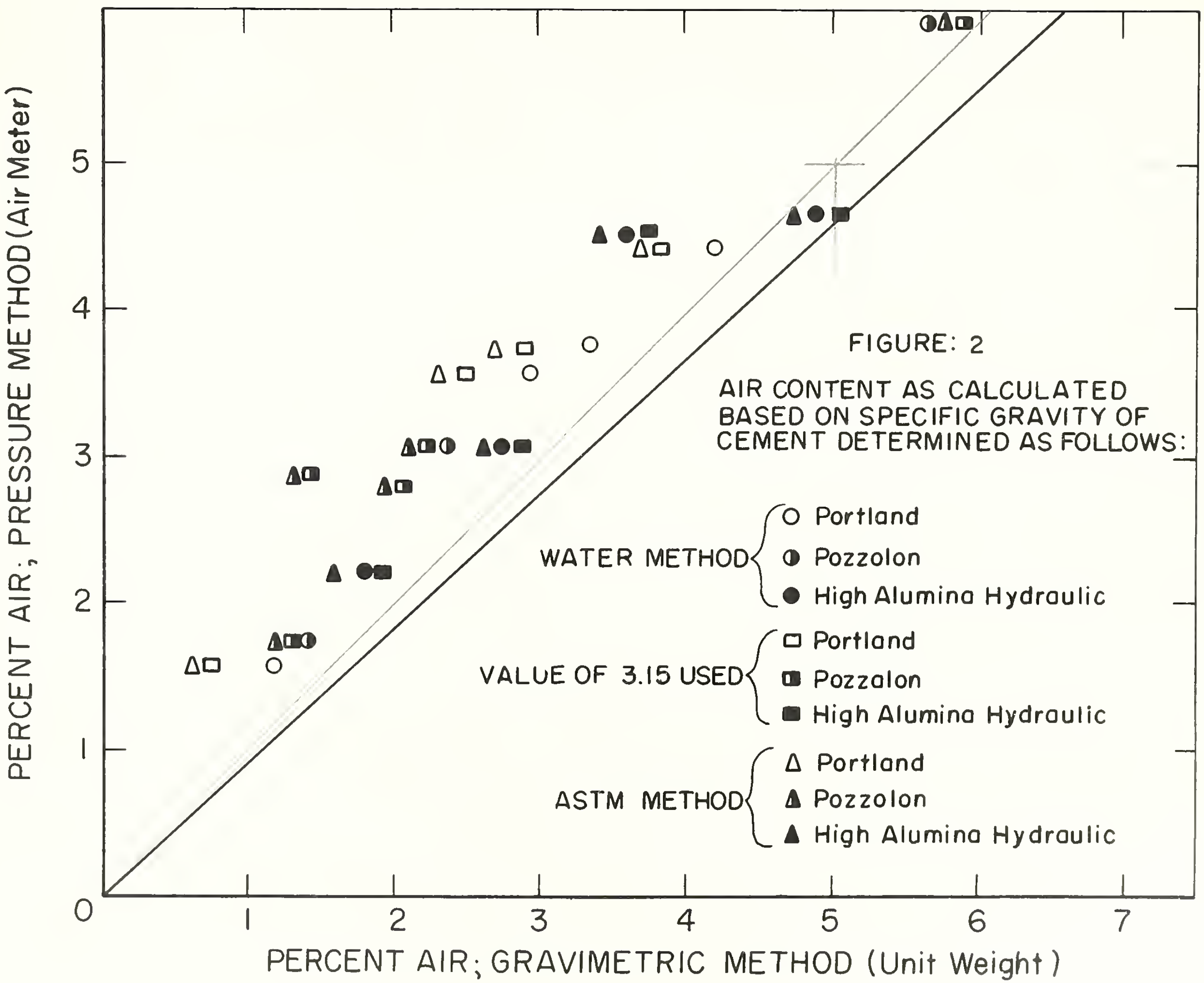
TABLE 2 - PROPERTIES OF FRESH[a/] CONCRETES (CONTINUED)

Identification[b/]	Proportions by Weight: Cement to Coarse and to Fine Aggregate	Cement Content	Vinsol Resin by weight of Cement	Water Content	Air Content: Gravimetric Method	Air Content: Air Meter Method	Slump	Weight of fresh Concrete	Water Cement Ratio	Remarks Fresh Concrete	Flexural Strength	Remarks Cured Concrete
		Sacks/yd^3 of Concrete	%	Gals/yd^3 of Concrete	%	%	inches	lbs/ft^3			psi	
F-B-A	1:3.25:1.53	5.80	.020	32.40	10.80	c/	3.0	128.14	.50	Placed well; sticky, over sanded	555	All over 1/2" aggregate: pull-outs; air voids present, especially around pull-outs.
F-B-B	1:3.12:1.47	6.54	.010	35.75	2.70	4.04	1.8	139.83	.49	Harsh but placed well	715	Few pull-outs; large air voids where aggregate pulled out; small voids distributed
F-B-C	1:2.79:1.28	7.00	.010	38.38	4.00	4.84	2.8	136.80	.49	do	---	---
P-B-D	1:2.54:1.13	7.58	.010	37.50	4.79	4.84	2.5	136.36	.44	do	---	---
Z-B-A	1:3.19:1.50	6.19	.015	35.80	5.65	c/	1.6	135.07	.51	Placed well sticky; over sanded	585	Large aggregate pulled out; large and small air voids around pull-outs
Z-B-B	1:3.06:1.44	6.35	.010	37.75	5.41	5.69	2.5	134.13	.53	Fair; would not place well any drier	555	Same as P-B-B
Z-B-C	1:2.67:1.22	7.42	none	38.40	2.37	3.11	1.5	139.83	.46	Fair; sticky increase water and aggregate	725	Few pull-outs; few large air voids
Z-B-D	1:2.51:1.13	7.85	none	40.60	1.30	2.22	1.5	140.69	.46	Harsh but placable	---	---
L-B-A	1:2.52;1.68	6.62	.030	35.22	8.08	c/	2.3	132.03	.47	Good placability slightly sticky	545	Large aggregate pulled out; air voids around pull-outs
L-B-B	1:2.47:1.65	6.76	.015	38.00	6.45	5.29	3.5	133.33	.50	Harsh but placable	605	Same as P-B-B
L-B-C	1:2.11:1.53	7.24	.010	41.60	7.15	6.54	7.0	131.17	.51	Placed well; too much water	---	---
L-B-D	1:2.11:1.53	7.94	.010	38.60	3.72	3.97	2.5	138.09	.43	Placed well; too dry	---	---

a/ For convenience the flexural strength of specimens, fabricated from trial batches and cured for 28 days in fog-room, are included, if tested.

b/ The first letters: P = Portland Cement; Z = Portland Pozzolan Cement; L = Lumnite, a high-alumina hydraulic cement.
The second letters: O = Olivine; B = Building Brick; OWM = Olivine and White Marsh Sand (+50 to -100).
The last letters: A to F inclusive, indicates trial mix made in a 1-cubic foot mixer.
The last numerals: 1 to 3 inclusive, indicate final selected mix made in 5-cubic foot mixer. Three batches of the selected mix were necessary to fabricate the required number of specimens.

c/ Above capacity of air meter.


PERCENT AIR; PRESSURE METHOD (Air Meter)
PERCENT AIR; GRAVIMETRIC METHOD (Unit Weight)
0
1
2
3
4
5
6
7
FIGURE: 2
AIR CONTENT AS CALCULATED BASED ON SPECIFIC GRAVITY OF CEMENT DETERMINED AS FOLLOWS:
WATER METHOD
Portland
Pozzolon
High Alumina Hydraulic
VALUE OF 3.15 USED
Portland
Pozzolon
High Alumina Hydraulic
ASTM METHOD
Portland
Pozzolon
High Alumina Hydraulic

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